ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 3, Issue 1, January 2018

Economic Comparison of Steel Bridge options for 35m Span

[1] Natraj Singh, [2] Dr. N.P Devgan, [3] Dr. Roshan Lal, [4] Surinder Pal, [5] Himanshu Jaiswa
[1] Dy. Chief Project Manager (IRSE), Dedicated Freight Corridor Corporation of India Ltd., India
[2] Senior Structural Consultant, PEC-Centre for Consultancy Engineering, Chandigarh, India
[3] Associate Professor, PEC University of Technology, Chandigarh, India
[4] Chief Project Manager (IRSE), Dedicated Freight Corridor Corporation of India Ltd., India
[5] Executive, Dedicated Freight Corridor Corporation of India Ltd., India

***Abstract:* -- The significance of the transport sector lies not only in the specific services it renders, but even more in unifying and integrating influences it renders on the economy. Railways, an integral part of the transport network, play a crucial role in facilitating trade. In a large developing country like India, railways are a medium of long-distance transportation of passenger and freight. Good physical connectivity in urban and rural areas is essential for economic growth and bridges plays a crucial role in achieving this target. Generally, project planners perform comparative cost analysis up to Composite Cost (material cost & placement of span) without considering lifecycle cost and effect of depth of girder on the cost of approaches. In this present study, analysis of the superstructure for 35m span have been performed under IRC loading with STAAD software and design has been carried out as per relevant IRC codes. An attempt has been made to include the factors of lifecycle cost and increase in overall cost of superstructure due to increase in the length of bridge approaches. After designing, estimation and costing of superstructure has been carried out. Afterwards taking into consideration of all the cost stages like Basic material cost, Composite cost, Lifecycle cost and Combined cost, it is seen that Composite steel girder comes out to be an economical option for the first three stages but the scenario changes in case of Combined cost and Steel Truss comes out to be the best choice.**

Key Words: - Composite Steel Girder, Steel Truss, Basic material cost, Lifecycle cost, Combined cost, and Sacrificial shuttering, etc.,

I. INTRODUCTION

A well-knit and coordinated system of transport plays an important role in the economic growth of a country. Transport routes are the basic economic arteries of the country. Transport system is regarded as the controller of the national economy and provides a very important link between production and consumption. The amount of traffic moving in a country is a measure of its progress. Evaluating how transportation and other infrastructure benefit the overall economy has been the subject of extensive economic literature. In the past to cope with the congestion in the transport sector, widening of roads, creation of new by-passes, and addition of new railway lines, addition in the density of rail/road network are being done so that capacity may be augmented further. For the growth of any country, funds are always a constraint for unlimited expansion. There are always many challenges to the planners of infrastructure projects to take maximum benefits of the available funds for creating the infrastructure with longer vision for sustainability.

In a country like India, importance of transport is more because of its vastness as well as varied nature of geographical conditions. In India, it is also a source of national integration, urbanization and globalization. The present Indian Transport system comprises several modes including rail, road, coastal shipping, air transport, etc. Transport has recorded a substantial growth over the years both in terms of length and output of the system. The transportation sector comprises of two arteries i.e., Road and Rail sector. The share of both modes in total freight traffic is estimated in the ratio of 35:65 in 12th plan. Growth in Railway passenger traffic is expected around 9% per annum, while in road traffic it is 15.4% per annum. Rail and road freight traffic are projected to grow at about 12% and 8% per annum respectively to achieve a 50% share each in the total freight traffic at the end of 15th plan (India Transport Report: Moving India Toward 2032, 2014). So as to achieve this target bridges plays a crucial role in interconnectivity of Road and Rail freight traffic. Bridges make the road and rail network more efficient by shortening routes and travel time and its construction cost involves a major share of any substantial big project. So it becomes the need of hour to strategic plan and chooses the type of bridge required according to the ground condition.

1.1 Composite Steel Girder Bridge

In case of Composite Steel Girder, steel structure of a bridge is fixed to the concrete structure of the deck so that the steel and concrete acts together thus minimizing deflections thereby increasing strength. Composite structure uses two dissimilar structural members in such a way that one acts in conjuction with the other (Ponnuswamy, S., 2009)[1]. By utilizing tensile strength of steel in the main girder and compressive strength of concrete in the slab, bending resistance of the combined material is greatly improved (Sarraf, Raed El., et.al, 2013)[2]. This is achieved by using shear connectors fixed to the steel beams and then embedded in the concrete.

1.2 Steel Truss

A truss bridge of conventional design consisting of the following parts: a deck slab, longitudinal stringers directly supporting the deck slab, cross beams at panel points accepting the load from the longitudinal stringers, the two main truss systems, lateral bracing provided in the planes of the upper and lower chords, end sway frames receiving the horizontal transverse forces from the lateral bracing and transferring these to the piers and additional immediate sway frames distributing the transverse loads to the late ral system and keeping the system stable during erection. In today's construction practices, designers customarily use bridges in the range of 30-35m span. So a study has been conducted to determine the economic implications of the type of bridge used.

II. SECTIONAL PROPERTIES

The analysis and design of superstructure depends upon type of loading, width of carriageway, number of longitudinal & cross-girders, spacing of girders etc. In present study, parameters of superstructure selected for comparison are given in Table 1.

Super structure type	Width of super structure (m)	Width of carriageway(m)
Composite Steel girder	11.23	7.5
Steel Truss	11.23	7.5

Table 1: Superstructure parameters for 35m span

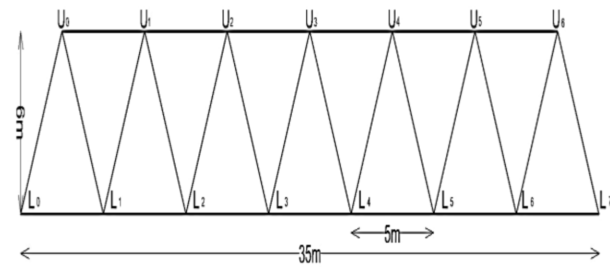

Figure 1: Warren Truss for 35m span

Warren truss for 35m span has been divided into seven panels of 5m each. The height of Through-truss has been kept 6m to accommodate vehicles as per IRC standards.

Table 2: Sectional properties of Steel Truss for 35m span

Description	Unit	Components in Steel Truss
Depth of deck slab	m	0.25
Number of panels	each	7
Length of panel	m	5
Height of truss	m	6
Top chord member	mm	Top flange plate= 520x25 2 ISMC 400
Bottom chord member	mm	2 No. Plates of 540x25

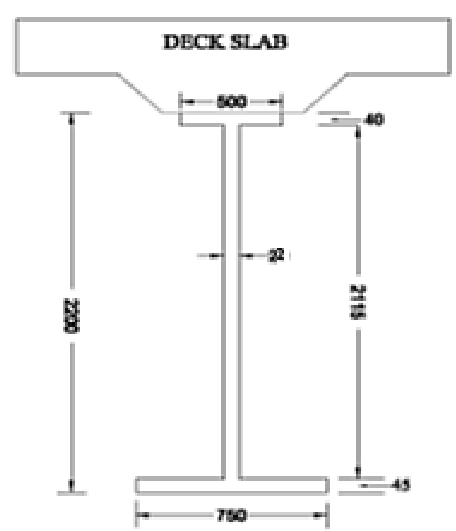

Figure 2: Composite Steel Girder for 35m span

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 1, January 2018

Table 3: Sectional properties of girders for 35m span

Description	Dimensions(m)
Depth of deck slab	0.25
Web depth (excluding deck slab)	2.2
Top Flange width (at mid span)	0.5
Web width (at mid span)	0.022
Web width (at support)	0.022
Bottom Flange width (at mid span)	0.75

III. ANALYSIS & DESIGN

The analysis for 35m span for Composite Steel Girder and Steel Truss has been carried out on STAAD software which is based on stiffness matrix approach. After carrying out the analysis, bending moment and shear force graphs have been developed for Composite Steel Girder to acknowledge the variations along the span. The variation of compression and tension forces due to live load (LL) and dead load (DL) for Steel Truss is given in Table 4.

It is evident from Table 4, tension force in bottom chord member increases from end chord member towards centre of span. Compression force in top chord member increases from end towards centre of span.

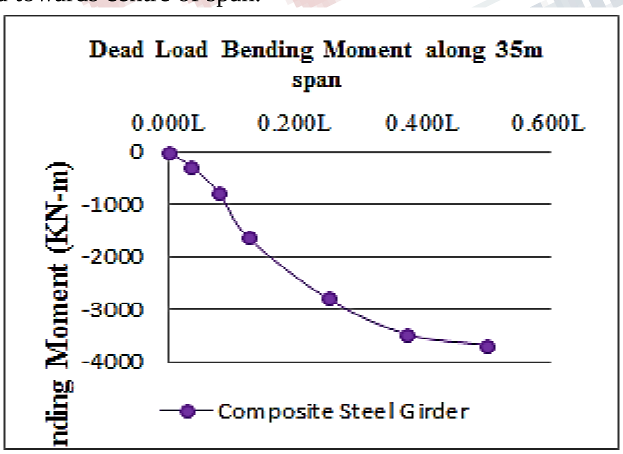

Figure 3: Variation in Dead load Bending Moment

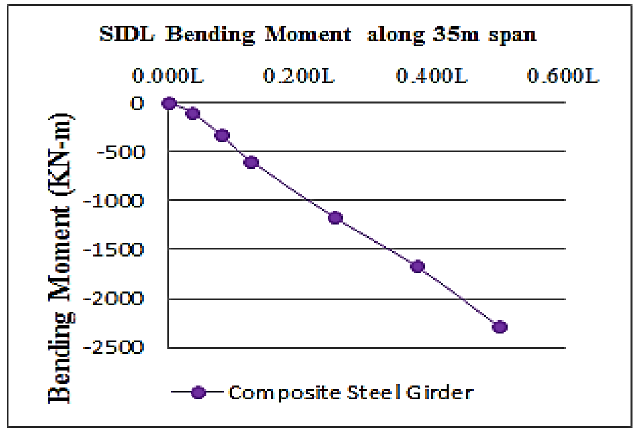

Figure 4: Variation in SIDL Bending Moment

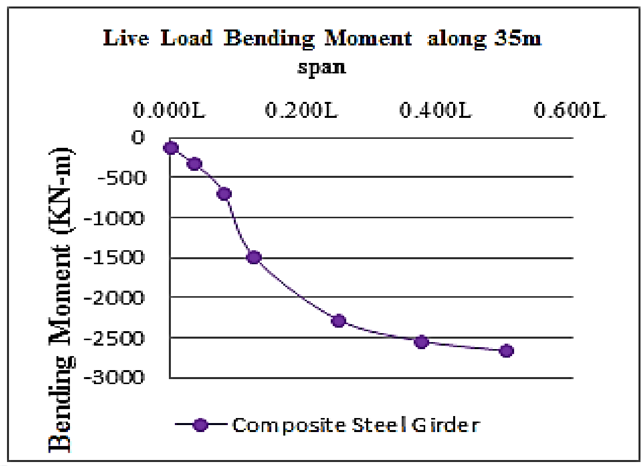

Figure 5: Variation in Live Load Bending Moment

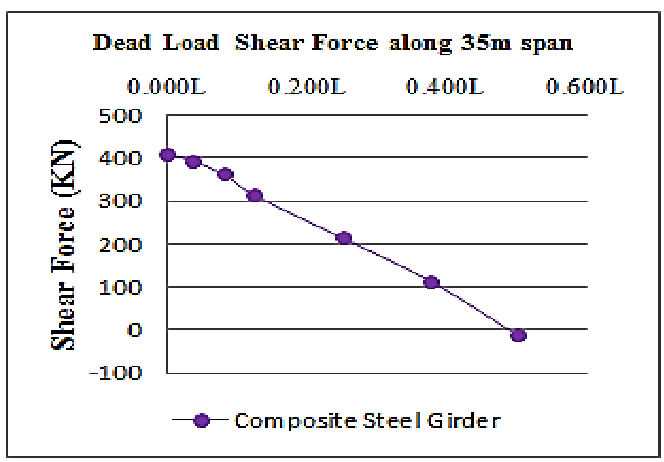

Figure 6: Variation in Dead load Shear Force

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 1, January 2018

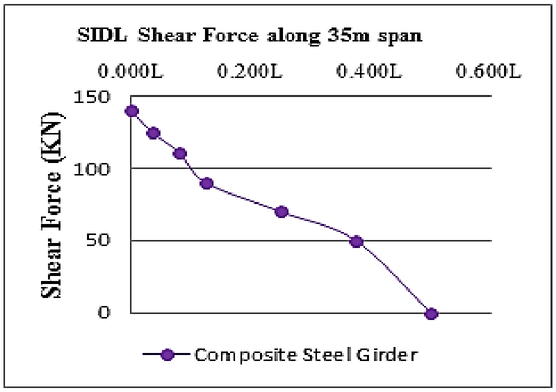

Figure 7: Variation in SIDL Shear Force

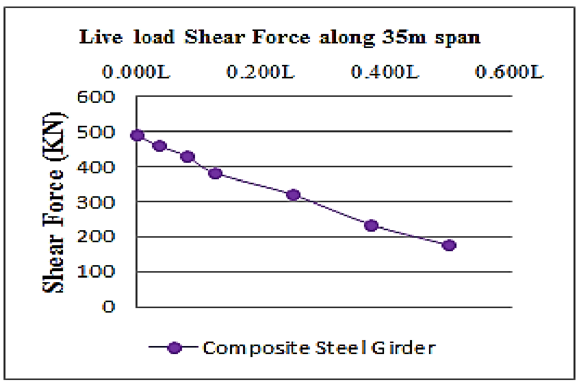

Figure 8: Variation in Live Load Shear Force

Table 4: Design Forces in Warren Truss members for 35m span

Member	Due to Live Load (KN)		Due to Dead Load (KN)	
	C	T	C	T
L_0L_1	-	215	-	505
L_1L_2	-	566	-	1340
L_2L_3	-	777	-	1840
L_3L_4	-	844	-	2005
U_0U_1	464	-	1083	-
U_1U_2	770	-	1799	-
U_2U_3	920	-	2155	-
U_3U_4	916	-	2155	-
U_0L_0	602	-	1410	-
U_0L_1	-	594	-	1370
U_1L_1	462	28	922	-
U_1L_2	25	465	-	915
U_2L_2	345	96	469	-
U_2L_3	95	345	-	452
U_3L_3	2024	204	9.63	-
U_3L_4	202	2025	4.32	-

Sections chosen for superstructure in Table 2 & Table 3 have been found safe from design criteria as per IRC standards.

IV. QUANTITY CALCULATION

The quantities of materials have been calculated based on design parameters. The total cost of bridge superstructure including placement/erection of span considering Normal Ground conditions has been calculated. Further concept of sacrificial shuttering for deck slab has been introduced. This shuttering is left permanently and does not require removal from the site. This concept is acquiring importance where there is a difficulty in getting the Railway traffic blocks and the cost repercussions are quite high.

Table 5: Quantities of materials required for superstructures for 35m span

Type of material consumed	Quantities of materials consumed		
	Unit	Composite Steel Girder	Steel Truss
Concrete	cum	98	98
Reinforcement	MT	21	19
Structural Steel	MT	154	135
Shuttering	sqm	377	377

V. COST ANALYSIS

The methodology of cost analysis is a process for calculating the cost based on the prevailing market rates of the materials used for construction. The cost analysis is done either by cost benefit analysis or comparative cost analysis. The comparative cost analysis is a method that facilitates designers of bridge to evaluate potential outcome and choose technologies to advance these outcomes. In present study, comparative cost analysis methodology is adopted to help decision maker to decide the best economical option among various available choices. Generally the cost analysis of any structure include following four components: i. e Basic material Cost, Transportation Cost, Placement/Launching Cost and Lifecycle cost of the structure. In addition to above four basic components, extra expenditure required for rising of approaches due to increase in depth of girder of superstructure is also considered in the comparative cost analysis. The rates for various components of work are based on bridge works being executed by Indian Railways and other agencies in Northern India. The tender rates are updated based on

Wholesale Price Index (WPI) released by Reserve Bank of India (RBI) for the current rates of May 2016. Further, these rates are compared with the rates taken from leading manufacturer/suppliers for final adoption. The rates for the shuttering in case of cast-in-situ and precast have been considered same and the rates for the steel in case of Composite Steel Girder and Steel Truss are inclusive of the cost of painting.

5.1. Basic Material Cost

Basic material cost involves cost of materials, cost of human resources and plant & machinery for its fabrication. Among two types of superstructures used in the study, it is assumed that precast/prefabricated girders are launched with the help of hydraulic cranes. The fabrication of girders and truss is considered to be carried out in nearby yard and casting of deck slab has been considered with two options, first with conventional shuttering and second with sacrificial shuttering. The basic material cost is calculated for both options after the detailed quantity calculation for 35m span.

Table 5: The comparative construction/fabrication (materials) cost of superstructure for 35m span with conventional and combination of conventional & sacrificial shuttering

Type of Superstructure	Construction/ fabrication cost (in Lakhs)	
	Conventional Shuttering	Combination of conventional & sacrificial shuttering
Composite Steel Girder	136.46	138.59
Steel Truss	142.64	144.77

To analyze the basic material cost, graphical presentation in form of bar chart is depicted in Figure 9

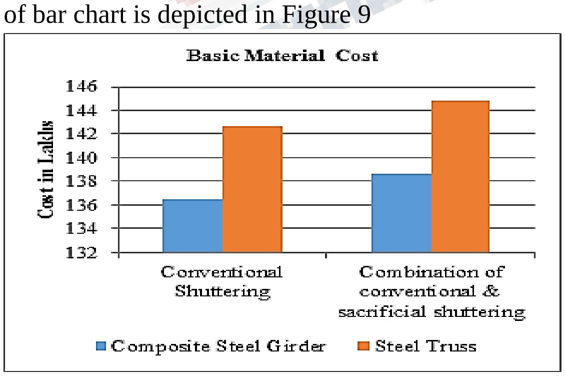

Figure 9: Variation of Basic material cost for 35m span of superstructure

As evident from Figure:9, basic material cost for Steel Truss is higher than Composite Steel Girder for both types of shuttering.

5.2 Transportation Cost

The cost for transportation is not included in the present study. It is assumed in this study that casting yard/fabrication yard is available in the vicinity of the construction site and there will be no additional cost for transportations of precast components of the superstructure.

5.3 Placement/Launching Cost

The placement/launching of the girder is the process of final placement of the girders on the piers at required bridge location. The cost associated with the placement/launching is greatly affected by the prevailing site conditions. Greater the restriction in the free movement of the cranes, more will be the cost involved with the placement of the girder.

Table 6: Weight of girders for different types of superstructures for 35m span

Type of Superstructure	Weight of Girders (MT)
Composite Steel Girder (single girder)	33
Steel Truss (complete truss)	135

The cost for placement/launching of girder is calculated by considering two cranes working simultaneously from both ends. There is no constraint on working hours of cranes and sufficient space is available for working of cranes.

Table 7: Launching cost of cranes for placement of various superstructures for 35m span

Launching cost of Girders for 35m span (INR) in Normal ground condition			
Superstructure type	No. of cranes required per Girder	Crane capacity combination (MT)	Cost for hiring of cranes per span
Composite Steel Girder	2	50+50	200000

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 1, January 2018

Launching cost of Girders for 35m span (INR) in Normal ground condition			
Superstructure type	No. of cranes required per Girder	Crane capacity combination (MT)	Cost for hiring of cranes per span
Steel Truss	2	150+150	1200000

The cost of crane has been taken for placement of complete span in one day. Composite cost is calculated by adding Basic material cost and Launching cost. Further Composite cost is calculated for both types of shuttering as given in Table 8.

Table 8: Composite cost details including Material cost & Launching cost with conventional shuttering & combination of conventional and sacrificial shuttering in Normal ground condition

Type of Superstructure	Composite Cost (in Lakhs)	
	Conventional Shuttering	Combination of conventional & sacrificial shuttering
Composite Steel Girder	138.46	140.59
Steel Truss	154.64	156.77

To analyze the effect of launching with basic material cost, graphical presentation in form of bar chart is depicted in Figure: 10.

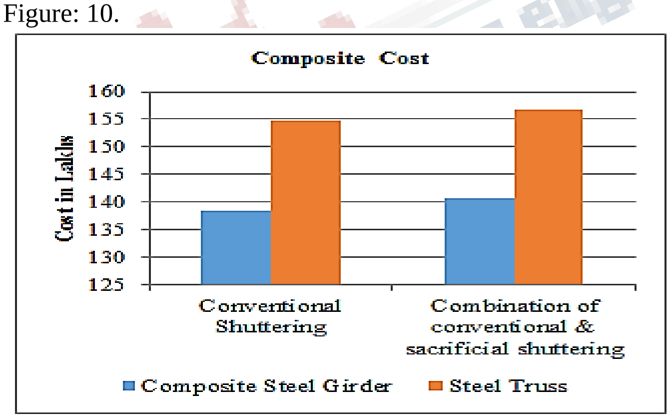

Figure10: Variation of Composite cost for 35m span of superstructure

As evident from Figure:10, composite cost for Steel Truss is higher than Composite Steel Girder for both types of shuttering.

5.4 Effect of Depth of Girder on the Cost of Approaches

The length of approaches will increase with increase in depth of girder. The gradient of approaches is generally taken as 1 in 30. The height of supporting girders for deck slab depends upon the type of material, its geometric shape, methodology of construction etc. The cost effect has been arrived at by calculating the extra depth of girder involved in comparison with girder of lowest height. The extra area requirement of retaining walls and abutments on both sides of approaches along with volume of earthwork is calculated. The detail of calculations is associated with extra cost of approaches is given in Table 9.

Table 9: Extra cost of approaches associated with Depth of girder with respect to girder of minimum depth for 35m span

Details	Unit	Type of superstructure	
		Composite steel Girder	Steel Truss
Depth of Girder	m	2.2	1.4
Extra depth in comparison with depth of Composite Steel Girder	m	0.8	-
Area calculation			
Standard area considering 9m height at abutment	m^2	1215	
Area with extra depth	m^2	1441	-
Increase in area of retaining wall	m^2	902	-
Extra area of Abutment	m^2	19	-
Total Area	m^2	922	-
Volume of Extra Earthwork	m^3	5414	-
Extra amount of Earthwork	INR	1624320	-
Extra amount of RE wall	INR	3225600	-
Total extra amount	**INR**	**4849920**	-

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 1, January 2018

5.5 Composite Cost including Effect on Approaches

The cost effect of extra depth of girder is added in composite cost (material cost and launching cost) with conventional shuttering taken from Table 8 for different types of superstructures with 35m span. For 35m span, depth of Steel Truss is minimum between two types of superstructure considered for cost comparison. Hence, effect of cost of depth of girder on the cost of approaches is calculated by taking Steel truss as a reference in case of 35m span.

Table 10: Composite cost including Effect of Depth of girder for combination of conventional and sacrificial shuttering

Type of superstructure	Composite Cost including effect of depth of Girder (in Lakhs)	
	Conventional Shuttering	Combination of conventional & Sacrificial Shuttering
Composite Steel Girder	186.96	189.09
Steel Truss	154.64	156.77

To appreciate the cost effect on approaches, bar chart for composite cost including effect of depth of girder on cost of approaches is presented in Figure 11.

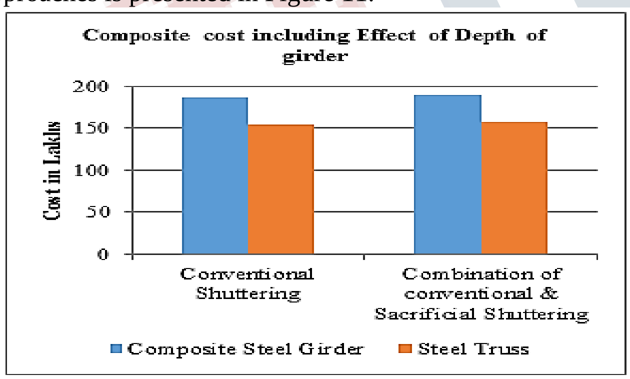

Figure 11: Variation of Composite cost including effect of depth of girder on cost of approaches for 35m span

As evident from Figure 11, Steel truss has become economical option in comparison with Composite steel girder for both types of shuttering.

5.6 Lifecycle Cost

In civil engineering, all the structures are designed for a definitive design life and they are expected to complete their intended design life with fulfilling the serviceability conditions as prescribed in codes. The bridges are generally designed for a design life of 100 years. The performance from durability point of view of newly built bridge and the recurrence cost of maintenance is generally the second most important component of the whole lifecycle cost (Pritchard, 1992)[3]. The economic evaluations based on total lifecycle costing are more appropriate than economic evaluations based on initial capital expenditures only (Weisskoff and Fauth, 2003)[4]. The periodic rehabilitation of the bridge component is an integral part of design life and depends on the constituent material and bridge type. The metal truss bridges were promoted as a more long lasting solution in spite of huge initial capital cost and heavy expenditure on periodic maintenance and the cost of upkeep was often perceived as a drain on country budgets (McKeel, Wallace. T., et. al, 2006)[5]. Lifecycle Cost for 35m span has been calculated by adding present value in the basic material cost and launching cost. It is assumed that design cost and construction cost are covered in material cost and launching cost. Further user cost is not considered as construction of bridge is assumed to be in green field conditions.

Table 11: Lifecycle cost consisting of Material cost, Launching cost, Maintenance cost in Normal ground condition

Type of superstructure	Lifecycle cost (in Lakhs)	
	Conventional Shuttering	Combination of conventional & Sacrificial Shuttering
Composite Steel Girder	146.60	148.83
Steel Truss	168.87	171.11

Lifecycle cost is higher for Steel truss than Composite Steel Girder and this position remains same as in Table 8.

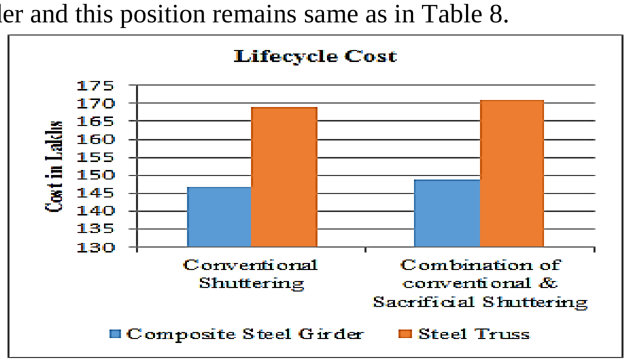

Figure 12: Variation of Lifecycle cost for 35m span of superstructure

To analyze the Lifecycle cost, graphical presentation in form of bar chart is depicted in Figure 12 and it is evident that cost of Steel truss is higher than Composite Steel Girder for both types of shuttering.

5.7 Combined Cost

The combined cost is arrived at by adding the lifecycle cost, effect of depth of girder on cost of approaches for conventional as well as combination of conventional and sacrificial shuttering.

Table 12: Combined Cost in Normal conditions with conventional and combination of conventional and sacrificial shuttering

Type of superstructure	Combined Cost in Normal condition (in Lakhs)	
	Conventional Shuttering	Combination of conventional & Sacrificial Shuttering
Composite Steel Girder	195.10	197.33
Steel Truss	168.87	171.11

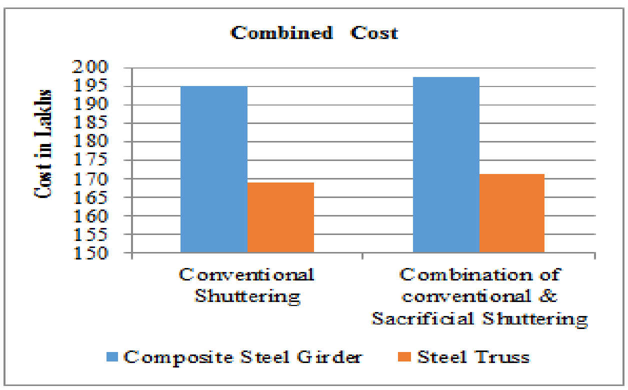

Figure 13: Variation of Combined cost for 35m span of superstructure

VI. CONCLUSIONS

In case of Basic material cost, superstructure with Composite Steel Girder is economical by 4.33% in comparison with Steel Truss for conventional shuttering. Considering Composite cost, superstructure with Composite Steel Girder is economical by 10.45% in comparison with Steel Truss for conventional shuttering. The percentage variation in cost in above both cases is reflected due to high cost of hiring of cranes in case of Steel truss in comparison with Composite Steel Girder.

Considering Lifecycle cost, superstructure with Composite Steel Girder is economical by 13.18% in comparison with Steel Truss for conventional shuttering. Taking in account of combined cost, superstructure with Composite Steel Girder is costlier by 15.53% in comparison with Steel Truss for conventional shuttering. The choice of economical option has changed in the combined cost category because of effect of depth of girder on cost of approaches comes into play.

The use of combination of conventional and sacrificial increases the overall cost of superstructure. This is more useful where traffic underneath the superstructure cannot be diverted. For expedite the construction time schedule sacrificial shuttering is more useful than conventional shuttering.

REFERENCES

[1]. Ponnuswamy, S. (2009). "Bridge Engineering." Pub. Tata McGraw Hill Education Private Limited, New Delhi, Second Edition.

[2]. Sarraf, Raed El., Iles, David., Momtahan, Amin., Easey, David., and Hicks, Stephen. (2013). "Steel-concrete Composite Bridge Design Guide." NZ Transport Agency research report, New Zealand.

[3]. Pritchard, Brian. (1992). "Bridge Design for Economy and Durability." Pub. Thomas Telford, London.

[4]. Weisskoff, Richard., and Fauth, Gary. (2003). "Comparing Costs of Options for Reconstructing the 12th and 27th Avenue Bridges Over the Miami River." Miami River Commission Report.

[5]. McKeel, W.T., Miller, Jr., A.B., Clark, K.S., Saufley, R.W., Bushman, Jr., W.H., and Lester, T.L. (2006). "Best Practices for the Rehabilitation and Moving of Historic Metal Truss Bridges."